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Research Article

Self-service check-in kiosks in airport terminal planning: Static analysis on the airport check-in space

Sook Yee Wong

School of Technology Management and Logistics (STML), College of Business, Universiti Utara Malaysia

*** Corresponding author:** judywsy@yahoo.com

ABSTRACT

Self-service check-in kiosks are increasingly recognized as a cost-effective solution for expanding check-in capacity without the need for terminal building expansion. These kiosks serve as essential airport infrastructure, providing time savings for passengers, cost reductions for airlines, and optimized space utilization for airports. This study aims to investigate whether the claimed 49 percent reduction in required check-in space with the adoption of self-service check-in kiosks is valid and examines how various factors influence this space saving. A small sized airport with an average annual traffic of 1 million passengers and 500 Typical Peak Hour Passenger (TPHP) serves as the case study. Through static analysis, the study assesses the impact of failure rates associated with self-service check-in kiosks on overall space savings. The findings indicate that failure rates significantly diminish space savings, underscoring the importance of technology reliability in maximizing efficiency. Additionally, space savings are influenced by passenger demand, passenger profiles, processing times, queuing/waiting times and space per passenger. These results suggest that while self-service check-in kiosks can enhance operational efficiency and passenger satisfaction, their effectiveness is contingent upon managing technology reliability and understanding diverse passenger needs. Overall, this study highlights the potential of self-service check-in kiosk in improving airport operations while providing valuable insights for future implementations.

Keywords: Self-service check-in kiosks, space saving, processing & waiting time, failure rate, Airport 4.0

1. Introduction

As passenger numbers continue to rise and terminal space remains limited, airports are under significant pressure to optimize check-in processes while airlines seek to reduce operating costs. This context has led to the widespread implementation of self-service check-in kiosks [10], which have revolutionized the check-in experience [33] by automating traditional manual check-in process [3, 4, 18]. These kiosks expedite the check-in process and align the interests of airlines, airports and passengers by providing substantial benefits, including reduced waiting times, enhanced passenger satisfaction, increased check-in capacity, improved operational efficiency, cost savings, and space savings [10, 11, 15, 28, 36].

Research indicates that transitioning from traditional check-in counters to self-service check-in kiosks can yield a remarkable 49 percent reduction in required check-in space [15]. Major U.S. airlines have

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extensively adopted these self-service check-in kiosks [33]. For instance, American Airlines has installed over 700 self-service check-in kiosks across approximately 27 major U.S. airports, while United Airlines has implemented around 1,200 self-service check-in kiosks at 35 airports. Other U.S. airlines – such as America West, Continental, and Delta have also introduced between 200 to 1,000 self-service check-in kiosks at various U.S. Airports [27]. These implementations demonstrate that self-service check-in kiosks can effectively manage rising passenger volumes without necessitating extensive infrastructure expansions [33], all while maintaining customer service quality [25]. Consequently, many airlines are planning to expand their self-service check-in kiosk offerings and enhance web and mobile check-in services, reflecting a strategic shift towards increased automation and improved passenger experience [26]. The extensive adoption of these self-service check-in kiosks has become a pivotal strategy for airlines [11], aligning with their operational goals and addressing the growing demand for efficiency and customer satisfaction [10].

Despite their advantages, self-service check-in kiosks are susceptible to failures due to technical issues or human error, which can disrupt the check-in process [43]. Such failures lead to longer wait times [10, 29], and diminished service quality [43]. A study at Zurich Airport highlighted that these failures significantly impact passenger experiences during busy periods [40]. For instance, when a failure occurs at a self-service check-in kiosk, passengers may require assistance from airline agents and face additional wait times as they navigate the check-in process again. Industry estimates suggest failure rate range from 1 in 7 and 1 in 9 [29], indicating the necessity of careful considering these factors in airport terminal planning.

The literature reveals a notable gap regarding the impact of failures on the effectiveness of self-service check-in kiosks. Furthermore, existing empirical formulas from International Air Transport Association (IATA) do not account for these failure rates. Therefore, it is essential to incorporate failure rates into calculations for check-in space during airport terminal planning to ensure actual space savings are achieved. Using a small sized airport as case study, this paper aims to address this research gap by investigating whether the claimed 49 percent space savings by the Société Internationale de Télécommunications Aéronautiques (SITA) can be maintained when accounting for failure rates since existing IATA formulas do not consider these factors in calculating check-in space.

The objective of this study is to validate the claimed space saving of up to 49 percent associated with the adoption of self-service check-in kiosks and explode how various factors influence these savings. The focus will specifically on the check-in area due to its status as the highest traffic zone compared to other processing areas within the terminal building [23].

The findings from this research are intended to provide valuable insights for airport planners, airline and airport operators seeking to optimize check-in space in existing terminals or during future expansions. Effectively leveraging self-service check-in kiosks can free up space for non-aeronautical/commercial uses. This aligns with the Airport 4.0 concept of building smarter and smaller terminal facilities through technology integration. The results may have significant implications for financial planning and strategic development in airports facing capacity constraints.

2. Literature review

2.1. Overview of the aviation market toward the adoption of self-service check-in kiosks

The continues growth in air traffic has exerted significant pressure on airport infrastructure [2], particularly concerning scarce resources like traditional check-in counters. Insufficient check-in capacity can lead to long waiting lines [36], especially during peak flight schedules [42]. These waiting lines typically arise when the demand for services exceeds available capacity [30, 31]. For instance, passengers often find themselves waiting at either traditional check-in counters or self-service check-in kiosks before they can proceed with their airport journey.

Long waiting time at check-in can diminish satisfaction and negatively influence perceptions of service quality [8]. Consequently, minimizing waiting time is a primary objective for airports and airlines seeking to enhance service quality and improve overall passenger satisfaction [38]. Reducing wait times also indirectly affects passengers' stress levels, further influencing their overall travel experience [35]. From a commercial perspective, maintaining low stress levels among passengers is crucial; when passengers are less stressed, they are more likely to engage in commercial activities within airport [32]. According to a study by Airport Council International (ACI), a mere 1 percent increase in passenger satisfaction can lead to a 1.5 percent increase in non-aeronautical revenue at airports [17]. Notably, research indicates that passenger tend to seize impulse purchasing opportunities approximately 60 minutes before boarding – often referred to as "golden hour" in airport retail [32].

Among the most cost-effective strategies for reducing waiting times in airports is the automation of the check-in process through self-service check-in kiosks [4, 18]. These self-service check-in kiosks have been highlighted by the self-service industry to significantly reduce wait times, which is a key selling point for their adoption [7, 22]. Additionally, self-service check-in kiosks can effectively manage rising passenger volumes without necessitating extensive infrastructure expansions [33], all while maintaining customer service quality [25]. Consequently, both airports and airlines are increasingly implementing these self-service check-in kiosks to supplement or replace the traditional check-in counters [29]. This trend is further supported by predictions from the IATA, which forecasts that check-in process will eventually be performed exclusively through self-service check-in kiosks in the future [9]. In line with this shift, airport terminals should be designed to minimize waiting times, ensuring a more efficient passenger experience [13].

2.2. Difference between traditional check-in counter and self-service check-in kiosk

The airline industry is increasingly adopting cutting-edge technologies, particularly self-service check-in kiosks – a stand-alone machine which allow passengers to manage their check-in independently [6]. These kiosks not only save time for passengers, but also reduce operating costs for airlines [39]. As a result of their efficiency, many airlines are planning to expand both the number of self-service check-in kiosks and their web and mobile check-in services [26].

The primary distinction between the traditional check-in at counters and self-service check-in lies in the number of steps involved. Passengers using the traditional check-in counters experience a one-step process, where airline staff handle all aspects of check-in, including verifying documents and processing baggage [41]. In contrast, self-service check-in kiosks involve a two-step process where passengers first print their boarding pass and bag tag at the self-service check-in kiosks before proceeding to drop off their luggage [36].

Despite this two-step process, time spent at self-service check-in kiosks is often shorter than at traditional check-in counters. This is because airline staff at traditional check-in counters must perform multiple tasks – such as locating passenger's booking, assigning seats, weighing baggage, and printing boarding passes and bag tags, leading to longer wait time [36]. Self-service check-in kiosks streamline these tasks, significantly reducing queuing/waiting times and enhancing passenger interaction with airlines' offering [24].

The transition from traditional check-in processes to self-service check-in kiosks aligns with IATA's "Fast Travel Program", which aims to provide various self-service options throughout the passenger journey [19]. This shift is also part of broader digital transformation efforts aimed at creating future airports – referred to as Airport 4.0 concept [37].

2.3. Airport 4.0 concept

Airport 4.0 represents the next generation of digitally transformed airports, focusing on operational efficiency, enhanced passenger experiences, increased revenue generation and increased capacity utilization from existing infrastructures. This concept aligns closely with Industry 4.0 principles, which emphasize the digitization of processes across various industries [37].

Under the Airport 4.0 framework, several advanced technologies facilitate this transformation, which can be classified into seven key categories as shown in **Table 1** [37].

Table 1. Key Industry 4.0 functional categories and their related technologies.

Functional category	Description	Related technologies
Data analysis & processing	Technologies used for information processing	Machine leaning, data mining, artificial intelligence, authentication, blockchain
Simulation, visualization & modelling	Technologies used for increased perception, visualization, and utilization of information	Augmented reality (AR), virtual reality (VR), simulation, digital twin, building information modelling (BIM)
Cloud computing	Technologies to enable the delivery of computing services over the Internet	Cloud storage databases, servers, cloud-based collaboration tools
Mobile smart devices	Technologies that make use of intelligent devices and sensors for communication and presentation of information	Smartphones for accessing digital channels, tablets, smart glasses, wearables
Internet of Things (IoT)	Technologies that make use of Intelligent devices and sensors for communication and presentation of information	Sensors such as RFID, LIDAR, etc., wireless sensor networks (WSN), location detection technology, 5G networks
Additive manufacturing	3D printing technology for product development and customization of goods on a large scale	3D printing
Cyber-physical systems (CPS)	Systems or networks that make use of autonomous elements involving human-machine and machine-machine interfaces to coordinate and automate processes	Robots, automatic guided vehicles (AGVs)/automated vehicles (Avs), self-service technologies (SSTs)

Source: *[37]*

Cloud computing plays a crucial role in the implementation of self-service check-in kiosks. These self-service check-in kiosks optimize the check-in process by allowing passengers to manage their check-in independently, thereby addressing challenges associated with the increased passenger volumes [37].

3. Methodology

3.1. Static analysis

For this study, static analysis is utilized to calculate the check-in space required at airports. This method is based on historical data and empirical formulas provided by IATA. Static analysis serves as a straightforward and effective tool for evaluating system behavior during peak periods, making it a preferred approach for preliminary planning, master planning and conceptual design phases [14].

Among the empirical methods available, the most widely used is IATA's Airport Development Reference Manual (ADRM), which provides guidelines and formulas for airport planning and development

[12]. For this study, the required check-in space will be calculated using the following formulas derived from the IATA's ADRM [20]:

a) Formula 1 is used to calculate the number of traditional check-in counters, self-service check-in kiosks or self-service bag drops needed to accommodate peak passenger demand.

Check-in counters/ kiosks/ bag drops = $\frac{Demand \cdot PT/60}{\Delta t + MQT}$

In this formula:

- Demand: Number of peak hour passenger
- PT: Processing times per passenger (in seconds)
- Δt: Design peak period (in minutes)
- MQT: Maximum queuing time (in minutes)

b) Formula 2 calculates the maximum number of passengers that can be in queue at any given time based on available check-in resources.

Passengers in queue = $\frac{CD \cdot MQT}{PT/60}$

In this formula:

- CD: Number of check-in counters/kiosks/bag drops derived from Formula 1
- MQT: Maximum queuing time (in minutes)
- PT: Processing times per passenger (in seconds)

c) Formula 3 determines the required queueing area based on the maximum queue length and space allocated per passenger.

Queuing area = QMAX · SP

In this formula:

- QMAX: Maximum number of passengers waiting in queue derived from Formula 2
- SP: Space per person (in square meters)

3.2. Case study and scenarios

For this study, a small sized airport with an average annual traffic of 1 million passengers has been selected. Based on this annual passenger volume, the Typical Peak Hour Passenger (TPHP) is calculated to be 500 passengers. This TPHP figure is derived using methods proposed by the Federal Aviation Administration (FAA) – as shown in **Table 2** [15].

Table 2. Correlation between TPHP and annual traffic output from FAA.

Total Annual Passengers	TPHP as a % of annual flow
30 millions and over	0.035
20 – 29.9 millions	0.040
10 – 19.9 millions	0.045
1 – 9.9 millions	0.050
500,000 – 999,999	0.080
100,000 – 499,999	0.130
Less than 100,000	0.200

Assuming that one-way peak departures and arrivals account for 60 percent of the TPHP, this results in approximately 300 departure passengers and 300 arrival peak hour passengers (500 x 0.6). Based on this information, the check-in space required will be determined for the following five scenarios to meet the study's objectives:

a) Scenario 1 – Scheduled passengers check-in using 100% traditional check-in counters.
b) Scenario 2 – Scheduled passengers check-in using 100% self-service check-in kiosks.
c) Scenario 3 – Low-cost passengers check-in using 100% self-service check-in kiosks.
d) Scenario 4 – Scheduled passenger check-in using 100% self-service check-in kiosks, with self-service check-in kiosks failure rates at 12.5% and 25% (extreme).
e) Scenario 5 – Low-cost passenger check-in using 100% self-service check-in kiosks, with self-service check-in kiosks failure rates at 12.5% and 25% (extreme).

These scenarios will allow for a comprehensive analysis of the impact of different check-in methods and potential failure rates on required check-in space.

3.3. Inputs for IATA's empirical formulas

For this study, the inputs required for calculating the check-in space using IATA's empirical formulas are as follows:

a) Processing time

To address long queuing/waiting time at check-in, it is essential to reduce processing time [36]. Various applications, such as online check-in, self-service check-in kiosks and self-service bag drops, have been developed to expedite the check-in process [16]. Generally, the processing time required for traditional check-in counters is approximately twice that of self-service check-in kiosks [15]. The processing times range between 60-90 seconds for self-service check-in kiosks [29]. For this study:

- Processing time for traditional check-in counters: 120 seconds
- Processing time for self-service check-in kiosks: 60 seconds

b) Queuing/ Waiting time

Research [16] indicates that check-in queue/wait time constitutes approximately 61 percent of the total travel time within the airport journey. Additionally, a simulation study at Kansai International Airport in Japan found that queuing/waiting time at traditional check-in counters can occupy more than 80 per cent of the total time before boarding [34]. According to IATA, the optimum queuing/waiting time for self-service check-in kiosks is 1-2 minutes, while for traditional check-in counters is 10-20 minutes [21]. For this study:

- Maximum wait time for traditional check-in counters: 20 minutes
- Maximum wait time for self-service check-in kiosks: 2 minutes
- Maximum wait time for self-service bag drop: 5 minutes

c) Space per passenger

In terminal planning, the space occupied by a self-service check-in kiosk and traditional check-in counter is as follow [15]:

- Self-service check-in kiosks: 0.35 square meters
- Traditional check-in counter: 4.57 square meters

The required check-in space per passenger ranges from 1.3 square meters to 1.8 square meters per passenger [20]. For this study:

- Low-cost passengers: 1.3 square meters
- Scheduled passengers: 1.5 square meters (the higher space allocation is due to greater baggage volume)

d) Failure rate

In contrast to manufacturing, where companies strive for "zero defect" production, it can be challenging for airport to avoid service defects [17]. The estimated failure rate for similar self-service kiosks in other industries – such as the hotel industry, ranges between one in seven and one in nine, approximately 12.5 percent [29]. For this study, the following failure rate have been considered:

- 12.5 percent
- 25 percent (for extreme case)

4. Results and discussions

Based on IATA's empirical formulas - Formulas 1, 2 and 3, **Table 3** presents the results for the number of traditional check-in counters, self-service check-in kiosks, self-service bag drops, maximum queue passengers and the queuing area required to accommodate the 300 peak departure passenger for a small size terminal with an annual traffic of 1 million passengers.

In Scenario 1 – where 100% of traditional check-in counters are used, the total check-in space required is 147 square meters. In Scenario 2 – transitioning from traditional check-in counters to self-service check-in kiosks reduce the required check-in space to 72 square meters, representing a 51 per cent space saving. This reduction is 2 percent slightly higher than the 49 percent claimed by SITA, confirming findings from previous studies [10, 11, 15, 28, 36] that the adoption of self-service check-in kiosks allows airports to save space.

In Scenario 3, the space requirement further decreases to 65 square meters when the passenger profile changes from scheduled to low-cost. This additional 4 percent reduction in space saving is attributed to the lower baggage volume typically associated with low-cost passenger, compared to scheduled passenger [15]. Specifically, the space allocated for scheduled passengers is 1.5 square meters (average of two pieces of baggage), while for low-cost passengers, it is reduced to 1.3 square meters (average of one piece of baggage).

Table 3. The required check-in area size (square meters).

	Scenario 1 Schedule	Scenario 2a Schedule	Scenario 2b Schedule	Scenario 3a Low-cost	Scenario 3b Low-cost	Scenario 4a Schedule	Scenario 4b Schedule	Scenario 5a Low-cost	Scenario 5b Low-cost

	passenger using traditional check-in counters	**passenger using self-service check-in kiosks**	**passenger using self-service bag drops**	**passenger using self-service check-in kiosks**	**passenger using self-service bag drops**	**passenger using self-service check-in kiosks with failure rate 12.5%**	**passenger using self-service check-in kiosks with failure rate 25%**	**passenger using self-service check-in kiosks with failure rate 12.5%**	**passenger using self-service check-in kiosks with failure rate 25%**
Number of peak hour passenger	300	300	300	300	300	300	300	300	300
Input									
Processing time (seconds)	120	60	60	60	60	60-120	60-120	60-120	60-120
Design peak period (in min)	60	60	60	60	60	60	60	60	60
Max wait time (min) for pax	20	2	0	2	0	20	20	20	20
Max wait time (min) for bag drop	0	0	5	0	5	5	5	5	5
Space per pax (m2)	1.5	1.5	1.5	1.3	1.3	1.5	1.5	1.3 -1.5	1.3 -1.5
Output									
# check-in counters/kiosks/ bag drops	8	5	5	5	5	1 counter, 5 kiosks, 5 bag drops	2 counters, 5 kiosks, 5 bag drops	1 counter, 5 kiosks, 5 bag drops	2 counters, 5 kiosks, 5 bag drops
Max # pax waiting in queue	75	10	23	10	23	33	33	33	33
Queueing area (m2)	113	15	35	13	30	64	78	55	67
Area for:									
Check-in counters (m2)	34	-	21		21	25	30	25	30
Self-service kiosks (m2)	-	2	-	2	-	2	-	2	2
Queueing area (m2)	113	15	35	13	30	64	78	55	67
Counters/kiosks + Queue area (m2)	147	16	56	14	51	90	109	82	99
TOTAL AREA REQUIRED (m2)	**147**	**72**		**65**		**90**	**109**	**82**	**99**
PERCENTAGE (%)	100%	49%		45%		61%	74%	56%	67%
SPACE SAVING (%)		51%		55%		39%	26%	44%	33%
SPACE SAVING Increased/decreased (%)		-51%		-4%		+12%	+25%	+7%	+18%

Considering failure rates of 12.5 percent and 25 percent (for extreme case) in Scenarios 4 and 5, the required check-in area for schedule passengers increases from 72 square meters to 90 square meters and 109 square meters, while the required check-in area for low-cost passengers increases from 65 square meters to 82 square meters and 99 square meters. This indicates that accounting for self-service check-in kiosks failure rate results in an increase in required check-in space of approximately 12 percent to 25 per cent for schedule passenger, while 7 percent to 18 percent for low-cost passenger. Indirectly, this suggests that higher failure rates lead to lesser overall space savings.

These findings emphasize the critical role that technology reliability plays in optimizing airport operations. As airports increasingly adopt self-service check-in kiosks, understanding how failure rates impact operational efficiency is essential for effective planning and resource allocation.

While the results derived from static analysis provide valuable insights into the impact of self-service check-in kiosk failure rate on space requirements, it is important to acknowledge several limitations. Static analysis [14] may not fully capture the complexities of real-world airport operations and dynamics. This method relies on historical data and empirical formulas, which can overlook variables that influence operational efficiency – such as unexpected passenger behavior or technical disruptions. Thus, dynamic analysis – particularly through simulation, is recommended for a more comprehensive understanding of airport processes. Simulation allows industry organizations to analyze their services in a virtual environment. However, it is essential to recognize that simulation methods can be time consuming and costly to implement. The need for accurate data input and the complexity of modeling various operational scenarios can pose significant challenges for airport management.

5. Conclusion

The adoption of self-service check-in kiosks is increasingly recognized as a viable solution for airports and airlines aiming to optimize space and achieve cost savings [15]. These self-service check-in kiosks can significantly reduce the required check-in area, enhancing passenger satisfaction and aligning with the Airport 4.0 concept, which promotes smarter, more efficient terminal designs. By minimizing processing and queuing/waiting times, self-service check-in kiosks not only increase check-in capacity, but also reduce the overall space needed for operations, making them a cost-effective alternative to terminal expansions, particularly for airports facing financial and land constraints issues.

This study highlights the importance of passenger profiles, demonstrating that low-cost passengers typically require less space per individual when utilizing self-service check-in kiosks, leading to greater overall space savings. However, the success of self-service check-in kiosks is contingent upon managing failure rates effectively. High failure rates can diminish space savings and lead to passenger dissatisfaction and abandonment of technology, particularly when immediate assistance is unavailable [43]. To mitigate these issues, providing personal assistance at the self-service check-in kiosks can enhance user experience by addressing problems promptly and reducing waiting times.

Given these insights, airport authorities should consider implementing policies that promote a hybrid model of check-in services. This model would maintain a small percentage of traditional check-in counters as backups to handle unforeseen failures while catering to passengers who prefer human interaction due to concerns about security or convenience [1, 5]. Simultaneously, targeted educational campaigns could encourage the adoption of self-service check-in kiosks by addressing common concerns and highlighting the benefits.

While static analysis provides a straightforward method for calculating space savings, it does not account for variations in terminal design layouts - such as linear versus island configurations, and passenger circulation patterns during preliminary planning. Future studies should consider employing dynamic analysis techniques - such as simulation, for a more comprehensive understanding of these factors. Overall, this study underscores the potential of self-service check-in kiosks in space saving, enhancing operational efficiency and passenger experience in airport terminal planning.

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Conflict of interest

The author declare no conflict of interest.

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